



US010072564B2

(12) **United States Patent**
Yasoshima et al.

(10) **Patent No.:** **US 10,072,564 B2**
(45) **Date of Patent:** **Sep. 11, 2018**

(54) **WASTE-GATE VALVE DEVICE**

(56) **References Cited**

(71) Applicant: **mitsubishi heavy industries
ENGINE & TURBOCHARGER,
LTD.**, Sagamihara-shi, Kanagawa (JP)

U.S. PATENT DOCUMENTS

2009/0090106 A1 4/2009 Muller
2010/0187460 A1 7/2010 An et al.
(Continued)

(72) Inventors: **Takeshi Yasoshima**, Tokyo (JP);
Motoki Ebisu, Tokyo (JP); **Noriyuki
Hayashi**, Tokyo (JP); **Yukihide
Nagayo**, Tokyo (JP); **Takeshi Yoshimi**,
Tokyo (JP)

FOREIGN PATENT DOCUMENTS

CN 101952568 A 1/2011
DE 10 2011 076 587 A1 11/2012
(Continued)

(73) Assignee: **mitsubishi heavy industries
ENGINE & TURBOCHARGER,
LTD.**, Kanagawa (JP)

OTHER PUBLICATIONS

(*) Notice: Subject to any disclaimer, the term of this
patent is extended or adjusted under 35
U.S.C. 154(b) by 10 days.

International Preliminary Report on Patentability and Written Opin-
ion of the International Searching Authority (Forms PCT/IB/338,
PCT/IB/373, PCT/ISA/237 and PCT/IB/326), dated Jul. 7, 2016, for
International Application No. PCT/JP2013/084672, together with
an English translation.

(21) Appl. No.: **15/039,968**

(Continued)

(22) PCT Filed: **Dec. 25, 2013**

Primary Examiner — Ngoc T Nguyen

(86) PCT No.: **PCT/JP2013/084672**

(74) *Attorney, Agent, or Firm* — Birch, Stewart, Kolasch
& Birch, LLP

§ 371 (c)(1),

(2) Date: **May 27, 2016**

(57)

ABSTRACT

(87) PCT Pub. No.: **WO2015/097786**

PCT Pub. Date: **Jul. 2, 2015**

To provide a waste-gate valve device with a good flow-rate
controllability. A waste-gate valve device 1 includes: a
turbine housing 3 provide with a waste-gate channel 2
through which exhaust gas bypasses a turbine; and a waste-
gate valve 4 to open and close an outlet of the waste-gate
channel 2. The waste-gate valve 4 includes a valve body 7
to open and close the outlet of the waste-gate channel 2, and
a protrusion 8 to be housed in the waste-gate channel 2 when
the valve body 7 closes the outlet of the waste-gate channel
2. The waste-gate channel 2 ensures a maximum flow rate of
exhaust gas at a time when the waste-gate valve is fully
open. An area ratio of a flow-path cross-sectional area A_1 of
the waste-gate channel 2 to a flow-path cross-sectional area
 A_2 of a merging portion is not more than 0.2, the merging
portion being a part at which exhaust gas having passed
through the turbine merges. A widened portion 2A at which

(65) **Prior Publication Data**

US 2017/0030261 A1 Feb. 2, 2017

(51) **Int. Cl.**

F02D 23/00 (2006.01)

F02B 37/18 (2006.01)

(52) **U.S. Cl.**

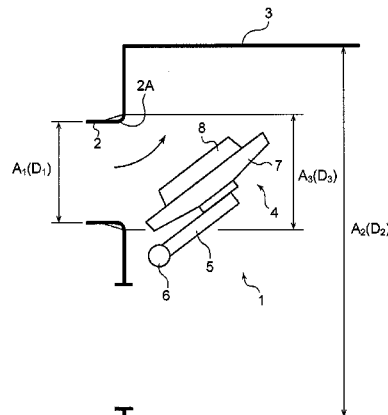
CPC **F02B 37/186** (2013.01); **F02B 37/183**
(2013.01); **Y02T 10/144** (2013.01)

(58) **Field of Classification Search**

CPC F02B 37/18–37/186

(Continued)

(Continued)



the flow-path cross-sectional area increases is disposed on the outlet of the waste-gate channel.

11 Claims, 12 Drawing Sheets

(58) **Field of Classification Search**

USPC 60/602
See application file for complete search history.

JP	63-177319	U	11/1988
JP	2-131032	U	10/1990
JP	4-95626	U	8/1992
JP	6-43227	U	6/1994
JP	2009-92026	A	4/2009
JP	2009-203835	A	9/2009
JP	2010-90714	A	4/2010
JP	2011-179401	A	9/2011
JP	2012-504727	A	2/2012
WO	WO-2013/098884	A1	7/2013
WO	WO 2013/128720	A1	9/2013

(56) **References Cited**

U.S. PATENT DOCUMENTS

2011/0005222	A1	1/2011	Hayashi et al.
2011/0173974	A1	7/2011	Grabowska
2012/0312010	A1	12/2012	Yasoshima
2013/0305711	A1	11/2013	Lueddecke et al.
2015/0014564	A1	1/2015	Nagayo et al.

FOREIGN PATENT DOCUMENTS

DE	10 2011 108 205	A1	1/2013
GB	2 066 365	A	7/1981
JP	S56-171631		12/1981
JP	58-2334	U	1/1983
JP	60-78941	U	6/1985
JP	62-156139	U	10/1987

OTHER PUBLICATIONS

International Search Report and Written Opinion of the International Searching Authority (Forms PCT/ISA/210, PCT/ISA/220 and PCT/ISA/237), dated Mar. 25, 2014, for International Application No. PCT/JP2013/084672.

Morimune et al., "Study of Compressible High Speed Gas Flow in Piping System—2nd Piping Systems with Sudden Enlargement," Transactions of the JSME, The Japan Society of Mechanical Engineers, B, vol. 46, No. 404, Apr. 25, 1980, pp. 653-660, along with a statement of relevance.

Extended European Search Report effective Nov. 23, 2016, issued in the corresponding EP Application No. 13900040.0.

European Office Action issued in corresponding EP Application No. 13900040.0 dated Oct. 16, 2017.

Chinese Office action issued in corresponding Chinese Application No. 201380080866.1 dated Oct. 31, 2017.

FIG. 1

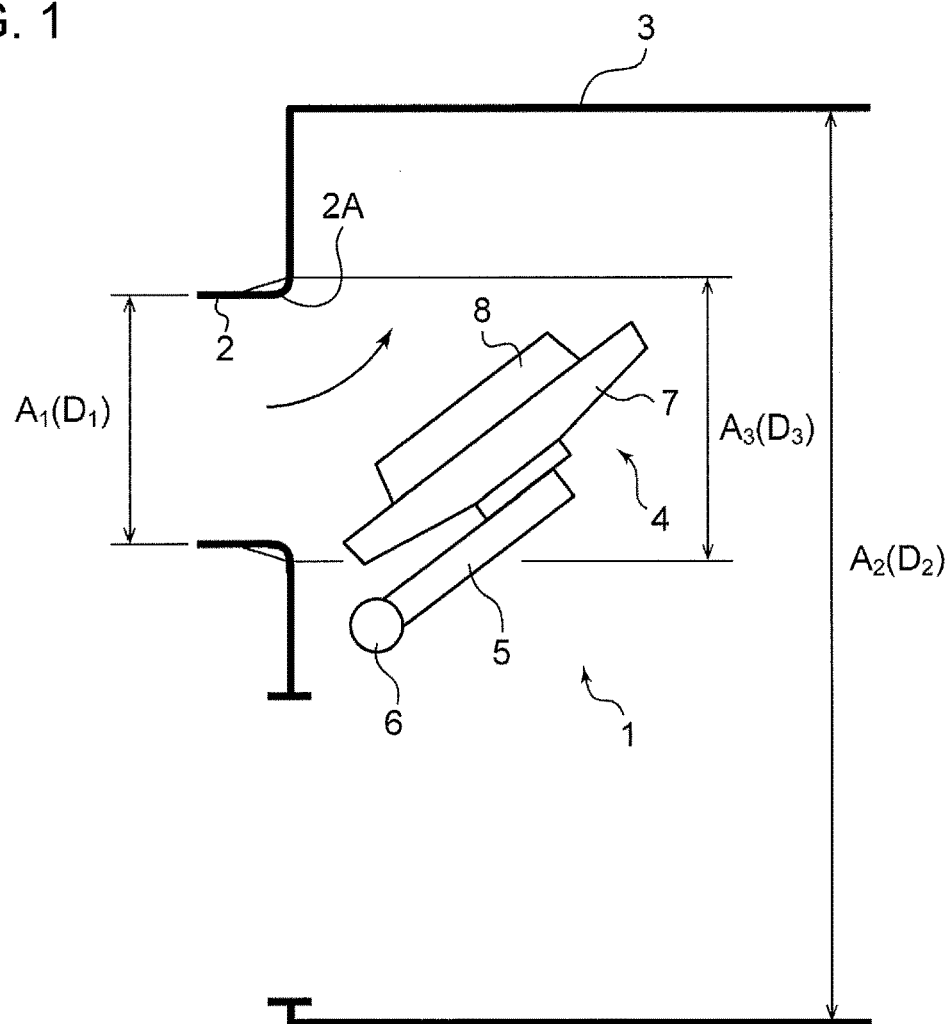


FIG. 2

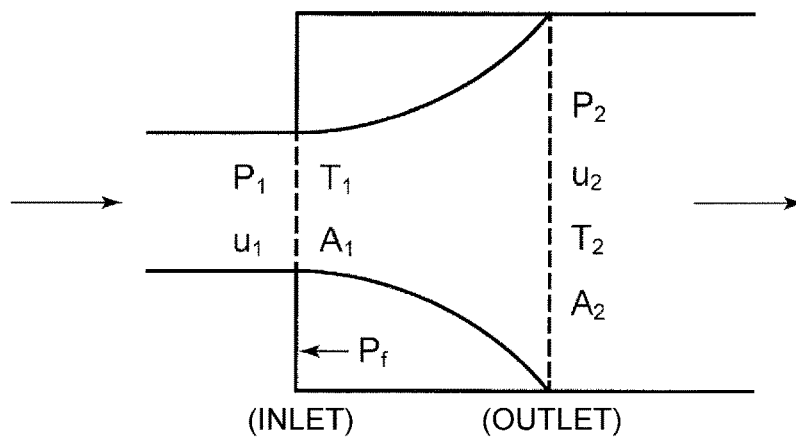


FIG. 3

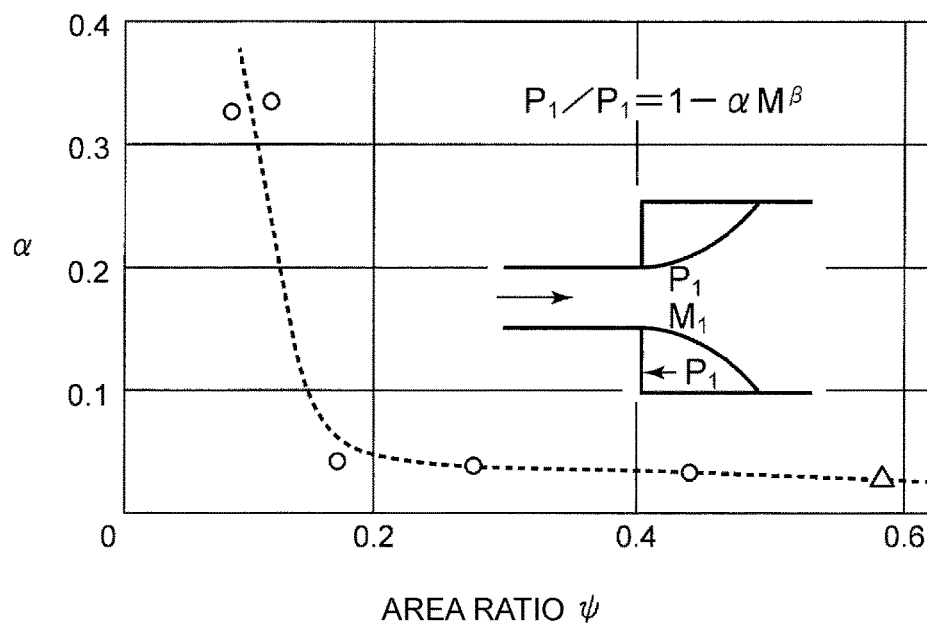


FIG. 4

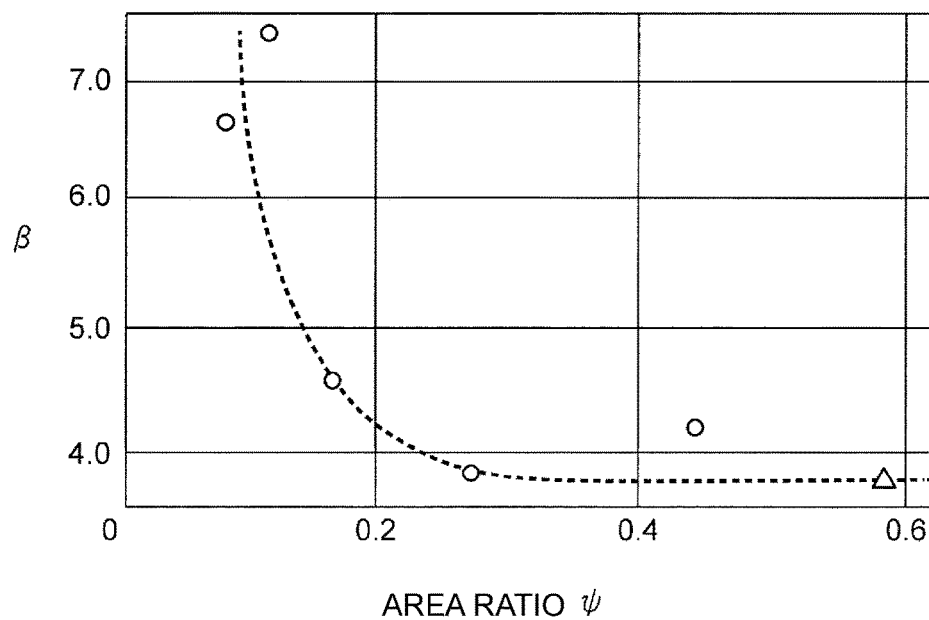


FIG. 5

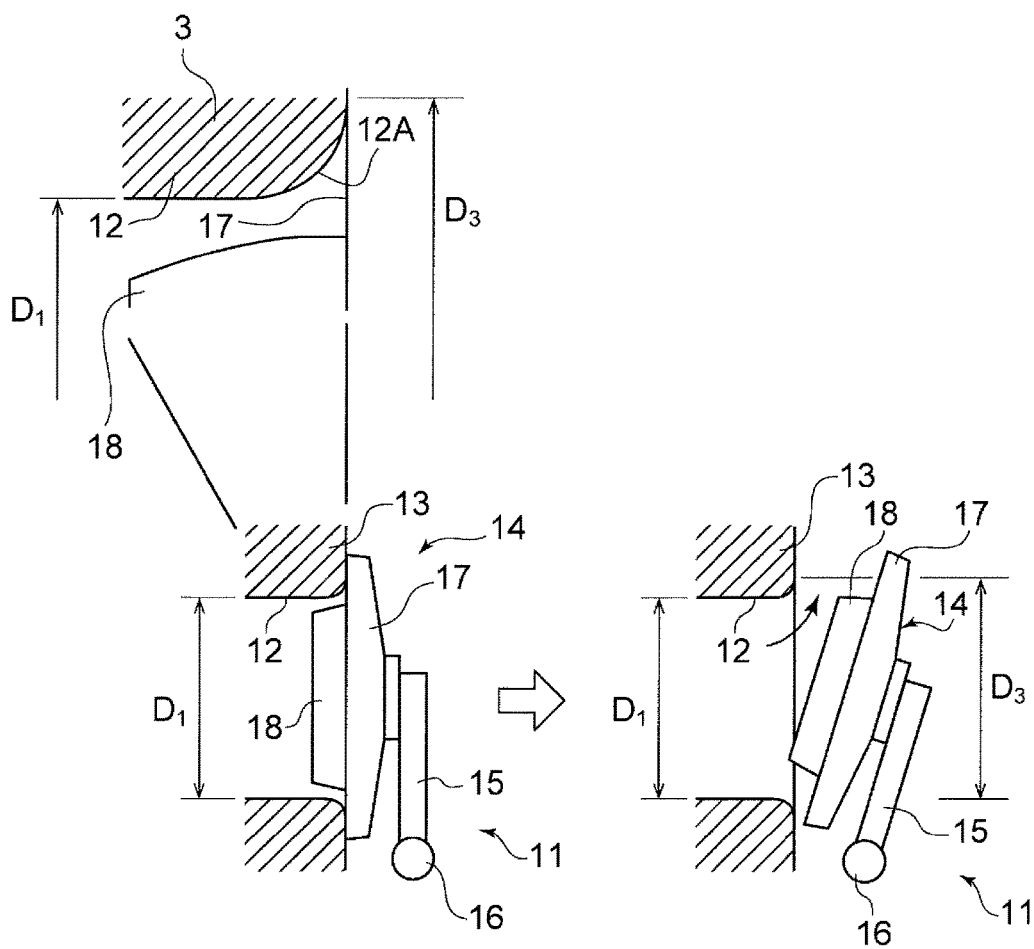


FIG. 6

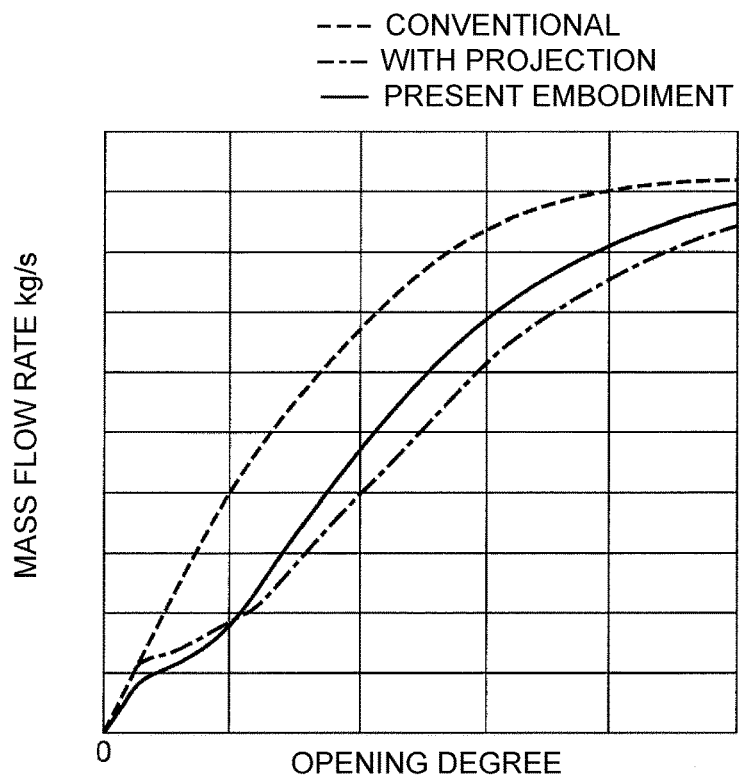


FIG. 7

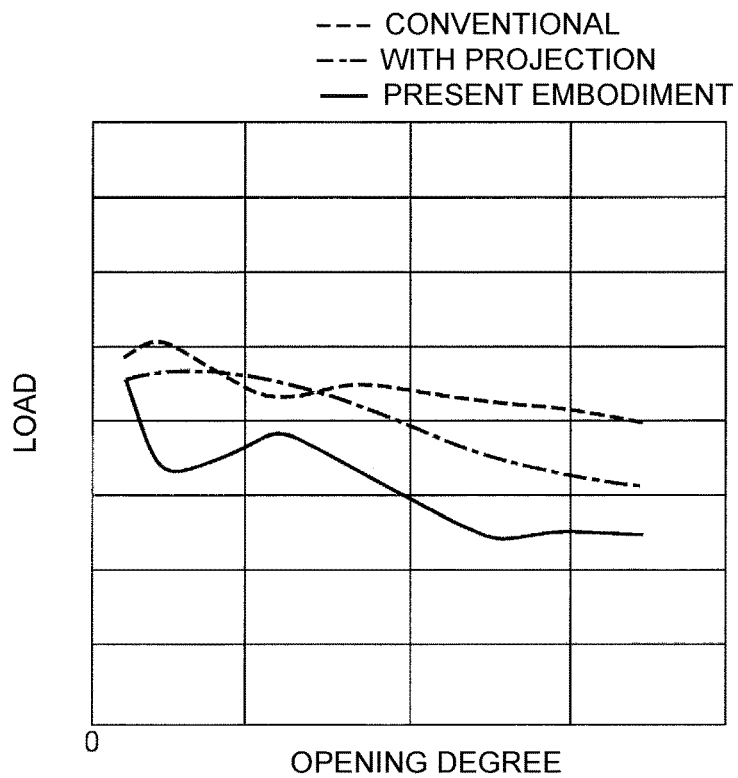


FIG. 8

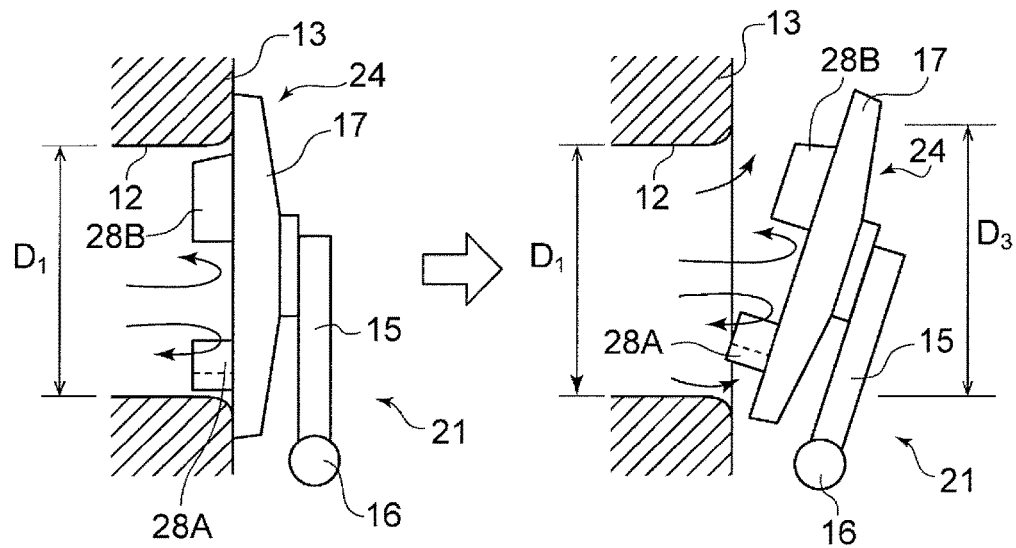


FIG. 9

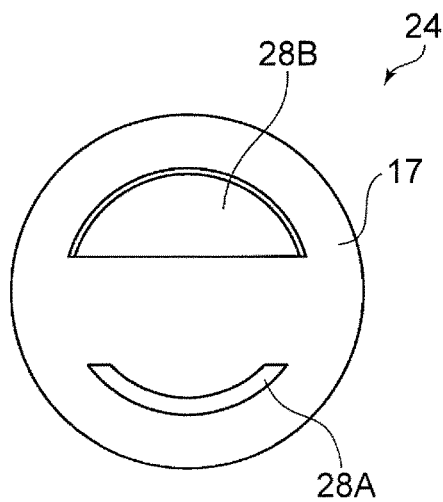


FIG. 10

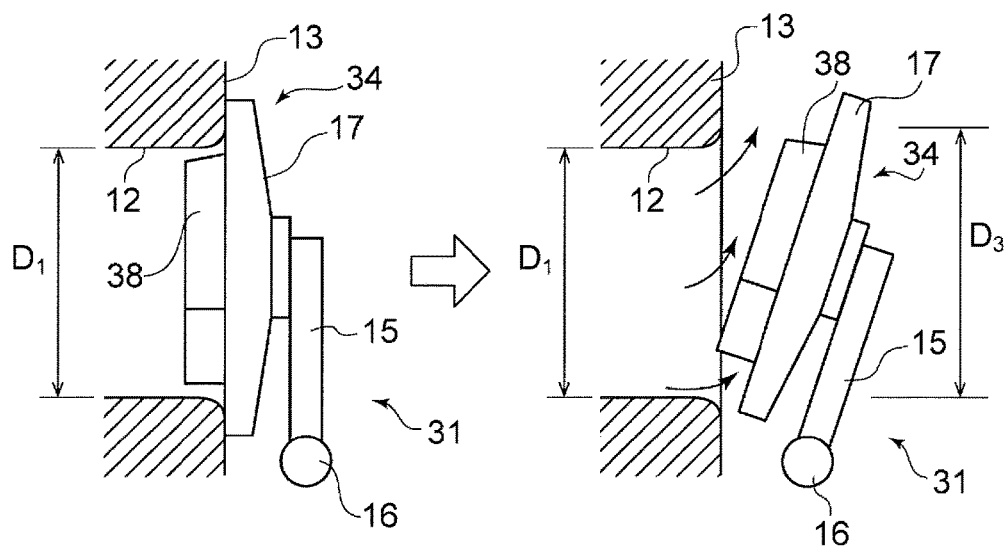


FIG. 11

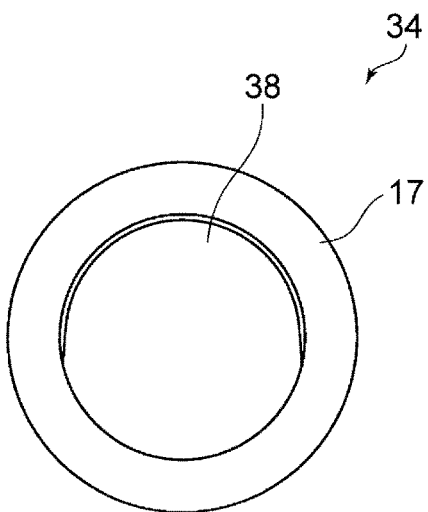


FIG. 12

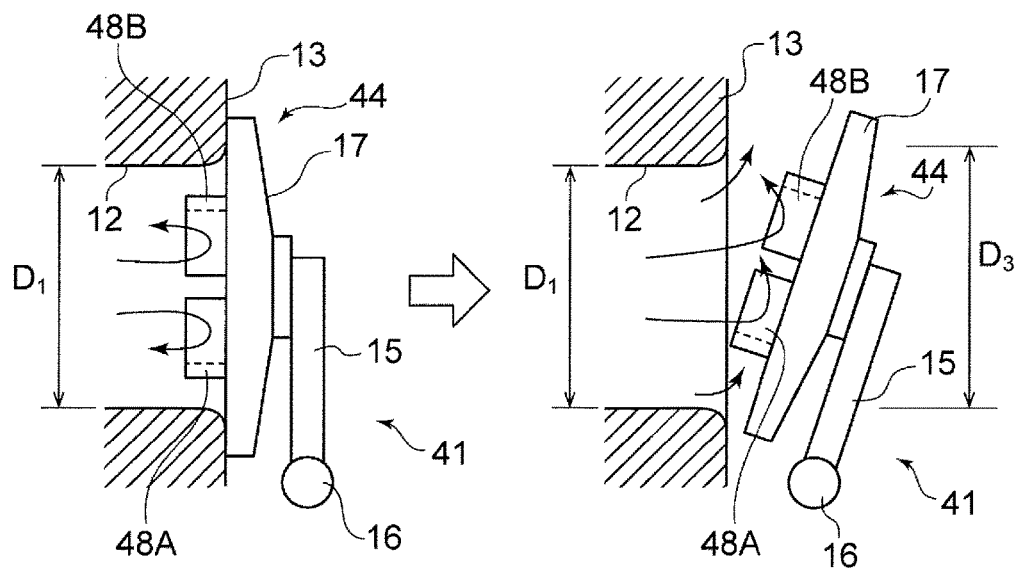


FIG. 13

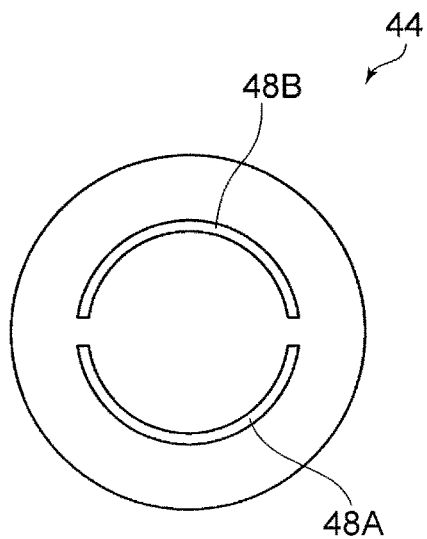


FIG. 14

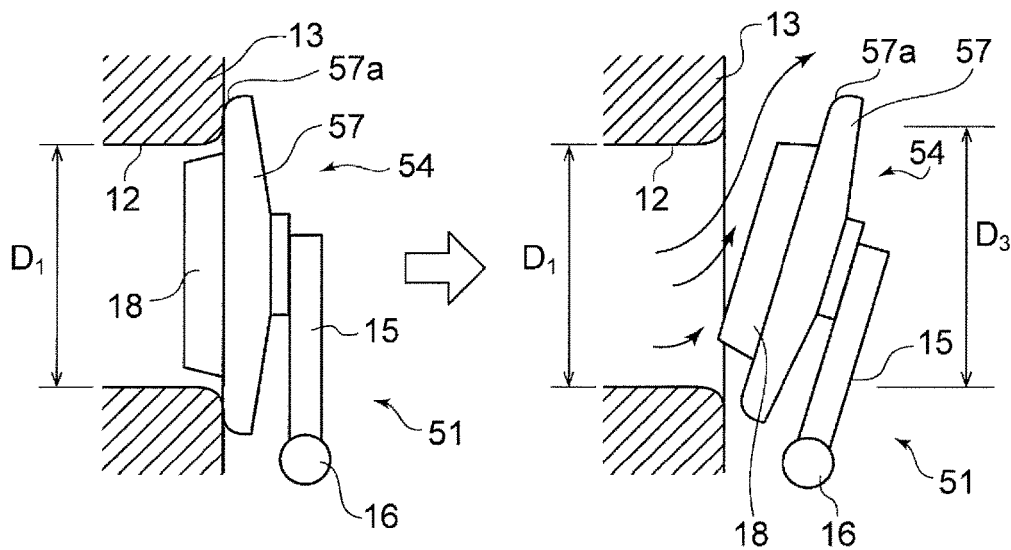


FIG. 15

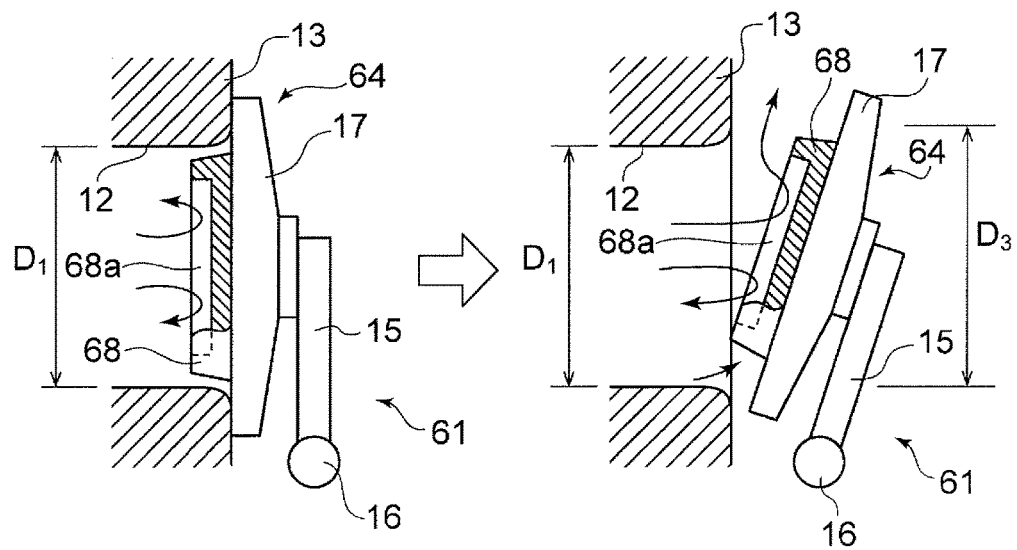


FIG. 16

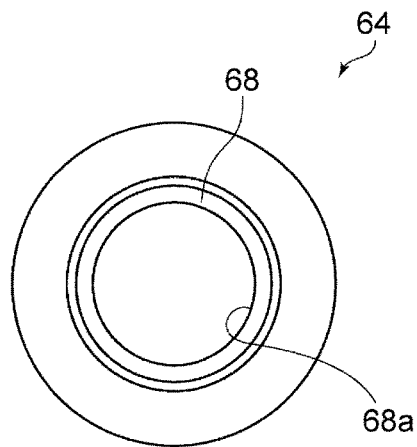


FIG. 17

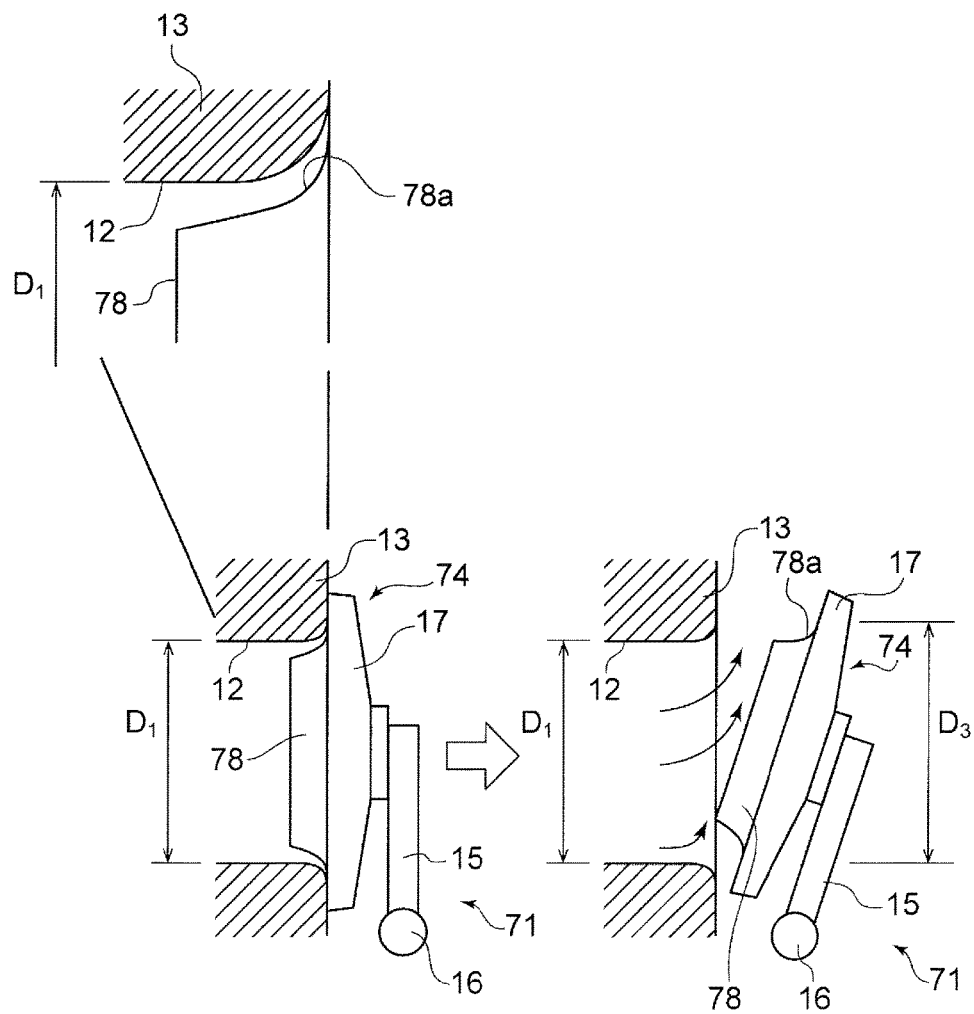


FIG. 18

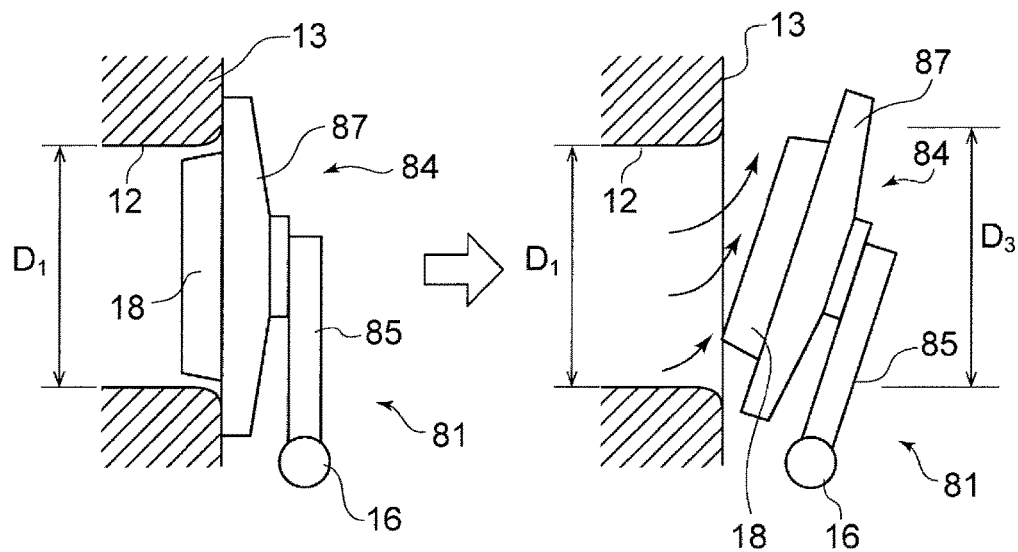


FIG. 19

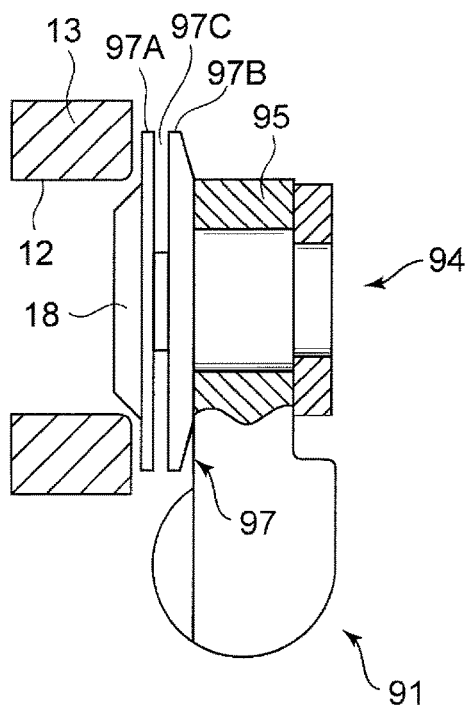


FIG. 20

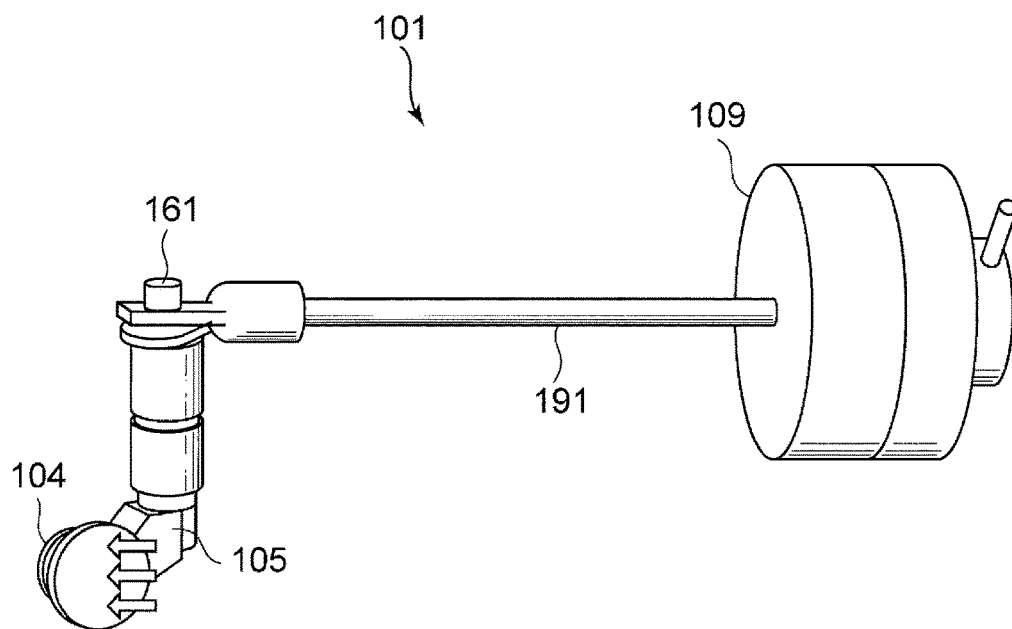


FIG. 21

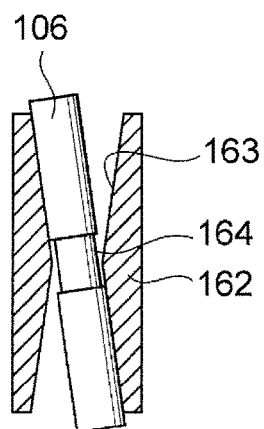
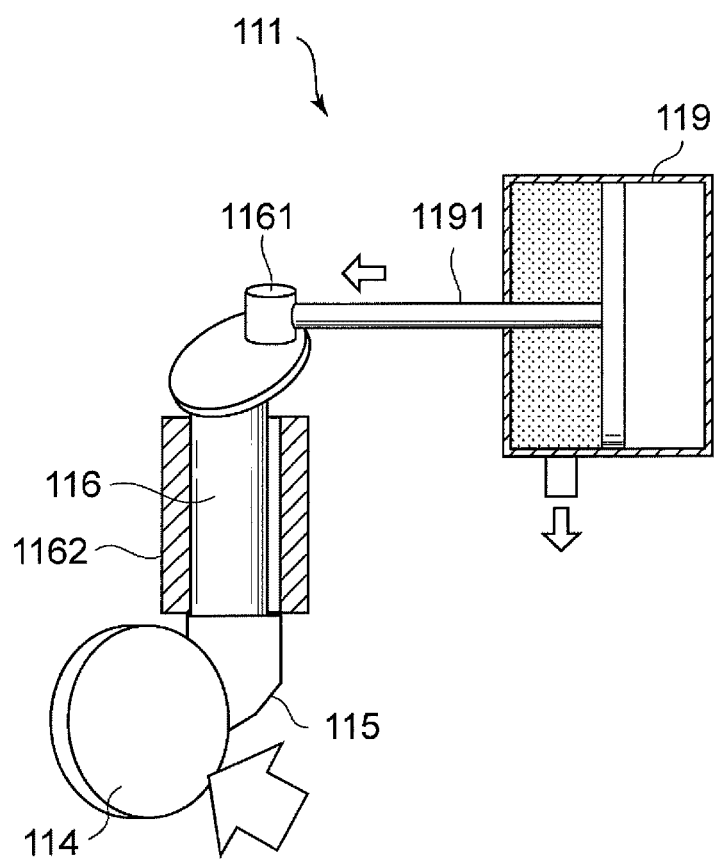


FIG. 22



WASTE-GATE VALVE DEVICE

TECHNICAL FIELD

The present invention relates to a waste-gate valve device which diverts a part of exhaust gas, in an engine supercharged by a turbocharger, to adjust a flow rate of exhaust gas entering a turbine.

BACKGROUND ART

Patent Document 1 discloses a waste-gate valve device with a waste-gate channel bypassing a turbine formed into a tapered shape widened from an inlet toward an outlet, with a valve body (waste-gate valve) for closing the outlet of the waste-gate channel including a protrusion of such a height that the protrusion is flush with an inlet-side wall surface of the waste-gate channel when the waste-gate channel is closed. With the above waste-gate valve device, when the valve body closes the waste-gate channel, the upper surface of the protrusion is flush with the inlet-side wall surface of the waste-gate channel, which makes it possible to reduce turbulence in an exhaust-gas flow at an inlet side of the turbine. Further, with the waste-gate channel having a tapered shape widened from the inlet toward the outlet, a larger gap may be formed between a side surface of the protrusion and an inner peripheral surface of the waste-gate channel even when the valve body is slightly open. Thus, it is possible to achieve a larger opening area for the waste-gate channel.

Patent Document 2 discloses a waste-gate valve device including a tapered portion at an outlet side of a waste-gate channel bypassing a turbine, so that a flow-path cross-sectional area gradually increases. With the above waste-gate valve device, a pressure-reduction region is formed between the tapered portion and a valve body (waste-gate valve), and the speed of an exhaust-gas flow bypassing the turbine increases in the pressure-reduction region, which makes it possible to reduce a force, especially a moment, applied to the valve body.

Patent Document 3 discloses a waste-gate valve device with a valve body (waste-gate valve) for closing an outlet of a waste-gate channel, the valve body including a protrusion on a surface adjacent to the waste-gate channel (a seating surface) formed to have a cross section of a “+” shape. With the above waste-gate valve device, it is possible to considerably reduce a negative pressure generated in clearance between the valve body and a valve seat due to turbulence of an exhaust flow flowing through a slight gap (clearance) between the valve body and the valve seat (outlet) at the outlet of the waste-gate channel.

CITATION LIST

Patent Literature

Patent Document 1: JPH4-95626U (Utility Model)
Patent Document 2: JP2009-203835A
Patent Document 3: JPS60-78941U (Utility Model)

SUMMARY

Problems to be Solved

However, with the above waste-gate valve devices described in Patent Documents 1 to 3, a flow rate cannot be sufficiently reduced when the valve body is slightly open

(hereinafter, referred to as “at the time of slight open”). Furthermore, a great load is applied when the valve body opens, which deteriorates flow-rate controllability.

The present invention was made in view of the above, and an object of the present invention is to provide a waste-gate valve device with high flow-rate controllability at the time of slight open.

Solution to the Problems

A waste-gate valve device according to the present invention comprises: a turbine housing comprising a waste-gate channel through which exhaust gas bypasses a turbine; and a waste-gate valve configured to open and close an outlet of the waste-gate channel, the waste-gate valve comprising a valve body configured to open and close the outlet of the waste-gate channel, and a protrusion configured to be housed in the waste-gate channel when the valve body closes the outlet of the waste-gate channel. The waste-gate channel ensures a maximum flow rate of exhaust gas at a time when the waste-gate valve is fully open. A flow-path cross-sectional area ratio of the waste-gate channel to a merging portion is not more than 0.2, the merging portion being a portion at which exhaust gas having passed through the turbine merges. A widened portion at which the flow-path cross-sectional area increases is disposed on the outlet of the waste-gate channel.

According to the present invention, a flow rate of exhaust gas flowing through the waste-gate channel increases, and thus it is possible to reduce a flow-path cross-sectional area of the waste-gate channel in accordance with an amount of the increase. As a result, flow-rate controllability of a flow rate of exhaust gas at the time of slight open of the waste-gate valve improves.

In an aspect of the present invention, a flow-path diameter D_1 of the waste-gate channel may satisfy a following expression 1, with respect to a relationship to a flow-path diameter D_2 of the merging portion.

$$D_1 \leq 0.469 \times D_2 - 0.5 \quad (\text{Expression 1})$$

In this way, it is possible to ensure machining accuracy and to achieve a suitable ratio of a flow-path cross-sectional area of the waste-gate channel to that of the merging portion.

Further, in an aspect of the present invention, an outlet diameter D_3 of the widened portion may satisfy a following expression 2, with respect to a relationship to the flow-path diameter D_1 of the waste-gate channel.

$$D_3 \geq 1.049 D_1 \quad (\text{Expression 2})$$

In this way, it is possible to achieve a suitable ratio of a flow-path cross-sectional area of the outlet of the widened portion to that of the waste-gate channel.

Further, in an aspect of the present invention, the protrusion may include a pressure-receiving portion configured to, when the waste-gate valve is opened, receive a pressure of exhaust gas flowing through the waste-gate channel, in a region close to a shaft supporting the waste-gate valve, and a reducing portion configured to reduce the flow of exhaust gas flowing through the waste-gate channel, in a region remote from the shaft.

In this way, the pressure-receiving portion can receive a pressure of exhaust gas in a region close to the shaft supporting the waste valve when the waste-gate valve opens, and the reducing portion can reduce a flow of exhaust gas in a region remote from the shaft.

Further, in an aspect of the present invention, the pressure-receiving portion may be formed in the region close to

3

the shaft, and the reducing portion may be formed in the region remote from the shaft.

In this way, the pressure-receiving portion can receive a pressure of exhaust gas in a region close to the shaft, and the reducing portion can reduce a flow of exhaust gas in a region remote from the shaft.

Further, in an aspect of the present invention, the pressure-receiving portion may be formed in an arc shape which forms a recess portion between the pressure-receiving portion and the reducing portion.

In this way, the recess portion can receive a pressure of exhaust gas effectively.

Further, in an aspect of the present invention, the protrusion may include a recess section which receives exhaust gas flowing through the waste-gate channel.

In this way, the recess portion can receive a pressure of exhaust gas effectively.

In an aspect of the present invention, a base portion of the protrusion may include an expanded portion which expands along an inner periphery of the widened portion.

In this way, it is possible to avoid stress concentration between the protrusion and the valve body.

In an aspect of the present invention, the valve body may have a rim portion disposed on a seating side of the valve body and formed into a shape of a curved surface.

In this way, exhaust gas having flowed through the waste-gate channel flows by the rim portion of the valve body smoothly, which makes it possible to reduce a load applied to the waste-gate valve.

In an aspect of the present invention, the valve body may comprise an end portion for opening and closing the waste-gate channel, a base portion, and an elastic-deformation portion disposed between the end portion and the base portion and configured to warp the end portion.

In this way, the end portion of the valve body warps if the waste-gate valve closes an outlet of the waste-gate channel, which makes it possible to ensure sealability of the waste-gate valve.

In an aspect of the present invention, the waste-gate valve device may further comprise: a drive shaft to which the waste-gate valve is fixed; and a bush supporting the drive shaft, and a tapered surface may be formed on an inner peripheral surface of the bush.

In this way, it is possible to prevent uneven contact of the drive shaft with the bush, and to prevent generation of an edge surface pressure.

In an aspect of the present invention, the waste-gate valve device may further comprise: a drive shaft comprising an end to which the waste-gate valve is fixed; a bush supporting the drive shaft; a lever pin disposed on another end of the drive shaft; and an actuator comprising a rod coupled to the lever pin. The lever pin and the actuator are disposed so that a pressure direction applied to the waste-gate valve coincides with an operational direction of the actuator.

Accordingly, a pressure direction of exhaust gas applied to the waste-gate valve coincides with an operational direction of the actuator. In this way, it is possible to prevent inclination of the drive shaft in the bush. As a result, it is possible to reduce leakage of exhaust gas outside the turbine housing through clearance disposed between the drive shaft and the bush.

Advantageous Effects

As described above, according to the present invention, pressure loss of exhaust gas flowing through the waste-gate channel is reduced, and a flow rate of exhaust gas increases

4

in accordance with an amount of the reduction. Thus, it is possible to reduce a flow-path cross-sectional area of the waste-gate channel in accordance with an amount of the increase in the flow rate of exhaust gas. As a result, it is possible to achieve good flow-rate controllability at the time of slight open of the waste-gate valve.

BRIEF DESCRIPTION OF DRAWINGS

FIG. 1 is a conceptual diagram for describing a waste-gate valve device according to an embodiment of the present invention.

FIG. 2 is a diagram of an analysis model of flow-path expansion.

FIG. 3 is a chart showing a relationship between an area ratio and coefficient α of an experimental expression.

FIG. 4 is a chart showing a relationship between an area ratio and coefficient β of an experimental expression.

FIG. 5 is a schematic diagram of a waste-gate valve device according to the first embodiment of the present invention.

FIG. 6 is a diagram of a relationship between an opening degree of a waste-gate valve of the waste-gate valve device illustrated in FIG. 5 and a mass flow rate of exhaust gas flowing through a waste-gate channel.

FIG. 7 is a diagram of a relationship between an opening degree of a waste-gate valve of the waste-gate valve device illustrated in FIG. 5 and a load applied to a shaft supporting the waste-gate valve.

FIG. 8 is a schematic diagram of a waste-gate valve device according to the second embodiment of the present invention.

FIG. 9 is a schematic diagram of the waste-gate valve illustrated in FIG. 8.

FIG. 10 is a schematic diagram of a waste-gate valve device according to the third embodiment of the present invention.

FIG. 11 is a schematic diagram of the waste-gate valve illustrated in FIG. 10.

FIG. 12 is a schematic diagram of a waste-gate valve device according to the fourth embodiment of the present invention.

FIG. 13 is a schematic diagram of the waste-gate valve illustrated in FIG. 12.

FIG. 14 is a schematic diagram of a waste-gate valve device according to the fifth embodiment of the present invention.

FIG. 15 is a schematic diagram of a waste-gate valve device according to the sixth embodiment of the present invention.

FIG. 16 is a schematic diagram of the waste-gate valve illustrated in FIG. 15.

FIG. 17 is a schematic diagram of a waste-gate valve device according to the seventh embodiment of the present invention.

FIG. 18 is a schematic diagram of a waste-gate valve device according to the eighth embodiment of the present invention.

FIG. 19 is a schematic diagram of a waste-gate valve device according to the ninth embodiment of the present invention.

FIG. 20 is a schematic diagram of a waste-gate valve device according to the tenth embodiment of the present invention.

FIG. 21 is a schematic diagram illustrating a drive shaft and a bush supporting the drive shaft.

5

FIG. 22 is a schematic diagram of a waste-gate valve device according to the eleventh embodiment of the present invention.

DETAILED DESCRIPTION

With reference to the accompanying drawings, embodiments of a waste-gate valve device according to the present invention will now be specifically described. The present invention should not be limited by the following embodiments.

FIG. 1 is a conceptual diagram for describing a waste-gate valve according to an embodiment of the present invention. FIG. 2 is a diagram of a model of flow-path expansion. FIG. 3 is a chart showing a relationship between an area ratio and coefficient α of an experimental expression, and FIG. 4 is a chart showing a relationship between an area ratio and coefficient β of an experimental expression.

A waste-gate valve device 1 diverts a part of exhaust gas, in an engine supercharged by a turbocharger, to adjust a flow rate of exhaust gas entering a turbine. As illustrated in FIG. 1, the waste-gate valve device 1 includes a turbine housing 3 with a waste-gate channel 2 through which exhaust gas bypasses a turbine (not illustrated), and a waste-gate valve 4 for opening and closing the waste-gate channel 2. The waste-gate valve 4 is fixed to a drive shaft 6 via a lever 5 and pivots about an axis passing through the center of the drive shaft 6, whereby the waste-gate channel 2 is opened and closed. Accordingly, while the waste-gate valve 4 is open, the flow path is narrowed at the side close to the drive shaft 6, and widened at the side remote from the drive shaft 6. Further, the waste-gate valve 4 according to the present embodiment includes a valve body 7 which opens and closes an outlet of the waste-gate channel 2, and a protrusion 8 which is to be housed in the waste-gate channel 2 when the valve body 7 closes the outlet of the waste-gate channel 2.

Exhaust gas having flowed through the waste-gate channel 2 merges with exhaust gas having flowed through the turbine, at a downstream side of the waste-gate channel 2. Thus, a flow-path cross-sectional area of exhaust gas flowing through the waste-gate channel 2 expands rapidly. It is known that rapid expansion in a flow-path cross-sectional area of exhaust gas may cause pressure loss, and related findings are disclosed in "Research Report of the R&D Sectional Committee on High-speed Flow of Gas in a Tube" (The Japan Society of Mechanical Engineers, 1978).

According to the document, an expansion surface pressure P_f is proposed as a parameter to represent pressure loss upon flow-path rapid expansion, as illustrated in FIG. 2. The more rapidly a flow path expands, the smaller the expansion surface pressure P_f is. With a decrease in the value (of expansion surface pressure P_f), greater turbulence occurs in an exhaust-gas flow, and the pressure loss increases. The expansion surface pressure P_f is expressed by the following experimental expression (expression 3).

$$P_f/P_1 = 1 - \alpha M_1^\beta \quad (3) \text{ (Expression 3)}$$

M_1 : Mach number

Meanwhile, as shown in the expression 1, the expansion surface pressure P_f is affected by coefficients α , β . As shown in FIGS. 3 and 4, coefficient α and coefficient β of the experimental expression change in accordance with an area ratio ψ , and rapidly changes at an area ratio $\psi(A_1/A_2)=0.22$ and below. Accordingly, the expansion surface pressure P_f changes considerably at an area ratio $\psi=0.22$ and below.

Even if a widened portion 2A is provided at the outlet of the waste-gate channel 2 having an area ratio $\psi(A_1/A_2)$ of 0.22 to expand the flow path, the area ratio $\psi(A_3/A_2)$ would

6

be 0.22 or higher. Thus, as illustrated in FIG. 1, an effect to expand the flow path (to reduce pressure loss) is reduced.

Further, if the minimum expansion is set to be 0.5 mm in diameter and a difference in area ratio of at least 0.02 ($A_1/A_2 - A_3/A_2$) is ensured, taking account of machining accuracy, a threshold value of A_1 with respect to A_2 can be defined by the following expression 4.

$$A_1 = 0.2 \times A_2 \quad (4) \text{ (Expression 4)}$$

Herein, the number in the expression 4 is 0.2 and not 0.22 because the position of an inflexion point is 0.22 as illustrated in FIGS. 3 and 4, and a difference in area ratio at a rapid-change region, which is approximately one-tenth ($0.22 \times 0.1 = 0.02$), is subtracted.

With the expression 4 converted into a flow-path diameter, the diameter D_1 can be obtained from the following expression 5.

$$D_1 = 0.447 \times D_2 \quad (5) \text{ (Expression 5)}$$

Here, given that $A_1 = (D_1/2)^2 \times \pi$, $A_2 = (D_2/2)^2 \times \pi$, and $A_3 = (D_3/2)^2 \times \pi$, the following expressions are satisfied:

$$A_1/A_2 \leq 0.2 \rightarrow D_1 \leq 0.447 D_2$$

$$A_3/A_2 \leq 0.22 \rightarrow D_3 \leq 0.469 D_2$$

$$D_3 - D_1 \geq (0.469 - 0.447) D_2$$

$$D_3 - D_1 \geq 0.022 \times D_2$$

$$D_3 - D_1 \geq 0.022 \times D_1 / 0.447$$

$$D_3 - D_1 \geq 0.049 D_1$$

Accordingly, a relationship (expansion width) of the outlet diameter D_3 of the widened portion 2A to D_1 can be expressed by the following expression 6.

$$D_3 - D_1 \geq 0.049 D_1 \quad (6) \text{ (Expression 6)}$$

Further as illustrated in FIGS. 3 and 4, since the area ratio $\psi(A_1/A_2)$ at the inflexion point is 0.22, if converted into a flow-path diameter, an expression of $D_1/D_2 = 0.469$ would be satisfied, which can be also expressed as an expression of $D_1 = 0.469 D_2$. Further, since the minimum expansion width is set to 0.5 mm taking account of machining accuracy as described above, the diameter D_1 of the waste-gate channel 2 is further reduced by 0.5 mm. Accordingly, the diameter D_1 of the waste-gate channel 2 is required to satisfy the following expression 7.

$$D_1 \leq 0.469 \times D_2 - 0.5 \quad (7) \text{ (Expression 7)}$$

Summarizing the above, for the waste-gate valve device 1 satisfying an expression of $D_1 < D_2$, where D_1 is the diameter of the waste-gate channel 2 and D_2 is the diameter of the merging portion, rapid expansion of a flow path is suppressed and pressure loss is reduced if D_1 , the diameter of the waste-gate channel 2, satisfies an expression of $D_1 \leq 0.47 D_2 - 0.5$, and D_3 , the outlet diameter of the widened portion 2A, satisfies an expression of $D_3 \geq 1.049 D_1$. Accordingly, it is possible to reduce the diameter D_1 of the waste-gate channel 2 in accordance with a flow rate increased by reduction of pressure loss. In this way, flow-rate controllability of the waste-gate valve device 1 is improved in accordance with a reduced amount of the diameter D_1 of the waste-gate channel 2.

First Embodiment

FIG. 5 is a schematic diagram of a waste-gate valve device according to the first embodiment of the present

invention. FIG. 6 is a diagram of a relationship between an opening degree of a waste-gate valve and a mass flow rate of exhaust gas flowing through a waste-gate channel, in the waste-gate valve device illustrated in FIG. 5. FIG. 7 is a diagram of a relationship between an opening degree of a waste-gate valve and a load applied to a shaft supporting the waste-gate valve, in the waste-gate valve device illustrated in FIG. 5.

As illustrated in FIG. 5, the waste-gate valve device 11 according to the first embodiment of the present invention includes a turbine housing 13 with a waste-gate channel 12 through which exhaust gas bypasses a turbine (not illustrated), and a waste-gate valve 14 for opening and closing the waste-gate channel 12. The waste-gate valve 14 is fixed to a drive shaft 16 via a lever 15 and pivots about an axis passing through the center of the drive shaft 16, whereby the waste-gate channel 12 is opened and closed. Accordingly, when the waste-gate valve 14 is open, the flow path is narrower at the side close to the drive shaft 16, and wider at the side remote from the drive shaft 16.

The diameter D_1 of the waste-gate channel 12 satisfies the above expression 7 while ensuring the maximum flow rate of exhaust gas at the time when the waste-gate valve 14 is fully open. For instance, if the diameter D_2 is 100 mm at the merging portion where exhaust gas having flowed through the waste-gate channel 12 and exhaust gas having flowed through the turbine merge (see FIG. 1), the diameter D_1 of the waste-gate channel 12 is set to not more than 44.6 mm, for instance, to 40 mm. Accordingly, the diameter D_1 of the waste-gate channel 12 according to the first embodiment is smaller than that of a conventional case, but the drive shaft 16 for driving the waste-gate valve 14 is disposed on the same position as that in a conventional case. As a result, the waste-gate channel 12 is positioned closer to the drive shaft 16.

A widened portion 12A is disposed on the outlet of the waste-gate channel 12. The widened portion 12A is to increase a flow-path cross-sectional area of the waste-gate channel 12, and the outlet diameter D_3 of the widened portion 12A satisfies the above expression 6. For instance, if the diameter D_1 of the waste-gate channel 12 is 40 mm, the outlet diameter D_3 of the widened portion 12A is set to at least 41.96 mm, for instance, to 42 mm. Accordingly, the widened portion 12A is gradually widened as illustrated in FIG. 5. In the example illustrated in FIG. 5, the widened portion 12A is gradually widened so as to form a curve (R) in cross section. However, configuration of the widened portion 12A is not limited to this, and may be gradually widened so as to form an oblique line in cross section.

Further, the waste-gate valve 14 according to the first embodiment of the present invention includes a valve body 17 which opens and closes an outlet of the waste-gate channel 12, and a protrusion 18 which is to be housed in the waste-gate channel 12 when the valve body 17 closes the waste-gate channel 12. The valve body 17 is formed into a disc shape having a size sufficient to close an outlet of the waste-gate channel 12, which is an outlet of the widened portion 12A. The protrusion 18 is formed into a truncated conical shape, and as described above, housed in the waste-gate channel 12 when the valve body 17 closes the outlet of the waste-gate channel 12. Also, when the valve body 17 opens the waste-gate channel 12, the protrusion 18 remains in a flow of exhaust gas having flowed the waste-gate channel 12, which improves flow-rate controllability of exhaust gas at the time of slight open. Thus, the size of the protrusion 18 is set in accordance with the diameter D_1 of the waste-gate channel 12. The larger the protrusion 18 is within

a range that the protrusion 18 can be housed in the waste-gate channel 12, the more the flow-rate controllability at the time of slight open of the waste-gate valve 14 improves.

Further, whereas the waste-gate valve 14 is connected to the drive shaft 16 for driving the waste-gate valve 14 via a lever 15, similarly to a conventional case, the lever 15 is formed to be shorter than that in a conventional case in accordance with a decrease in the distance between the waste-gate channel 12 and the drive shaft 16.

In the waste-gate valve device 11 according to the present embodiment of the present invention, the diameter D_1 of the waste-gate channel 12 satisfies the above described expression 7, and the outlet diameter D_3 of the waste-gate channel 12 satisfies the above described expression 6, which makes it possible to reduce pressure loss. Accordingly, it is possible to reduce the diameter D_1 of the waste-gate channel 12 in accordance with a flow rate increased by reduction of pressure loss. In this way, as illustrated in FIG. 6, flow-rate controllability of the waste-gate valve device 11 at the time of slight open is improved in accordance with a reduced amount of the diameter D_1 of the waste-gate channel 12. Further, the protrusion 18 is housed in the waste-gate channel 12 when the valve body 17 closes the outlet of the waste-gate channel 12, and remains in a flow of exhaust gas when the valve body 17 opens the waste-gate channel 12, which synergistically improves flow-rate controllability at the time of slight open. Further, since the lever 15 is shorter than that in a conventional case, a load applied to the lever 15 is smaller than that in a conventional case, as illustrated in FIG. 7, which also contributes to improvement of flow-rate controllability.

Second Embodiment

FIG. 8 is a schematic diagram of a waste-gate valve device according to the second embodiment of the present invention. FIG. 9 is a schematic diagram of the waste-gate valve illustrated in FIG. 8. A waste-gate valve device according to the second embodiment of the present invention is not different from the waste-gate valve device 11 according to the above described first embodiment of the present invention, except for protrusions 28A, 28B of a waste-gate valve 24. Thus, the same feature as that in the waste-gate valve device 11 according to the first embodiment of the present invention is indicated by the same reference numeral and not described in detail.

As illustrated in FIGS. 8 and 9, the waste-gate valve device 21 according to the second embodiment of the present invention includes a pressure-receiving portion (the first protrusion 28A) and a reducing portion (the second protrusion 28B) disposed on the waste-gate valve 24.

The pressure-receiving portion is to receive more pressure at a drive-shaft side of the waste-gate valve 24 when the waste-gate valve 24 opens. As illustrated in FIG. 8, the pressure-receiving portion according to the second embodiment includes the first protrusion 28A disposed in a region closer to the drive shaft 16 of a surface facing the waste-gate channel 12, in the waste-gate valve 24. The first protrusion 28A is disposed so as to form a recess portion between the first protrusion 28A and the reducing portion (the second protrusion 28B), and has an arc shape as seen from the side of the waste-gate channel, as illustrated in FIG. 9. The pressure-receiving portion (the first protrusion 28A) resists exhaust gas having flowed through the waste-gate channel 12, whereby a pressure is applied to the drive-shaft side of the waste-gate valve 24.

9

The reducing portion is to reduce a flow-rate change amount at the time of slight open of the waste-gate valve 24. As illustrated in FIG. 8, the reducing portion according to the second embodiment includes the second protrusion 18B disposed on a side remote from the drive shaft 16 of a surface facing the waste-gate channel 12, in the waste-gate valve 24. The second protrusion 28B has a substantially-halved truncated conical shape, as seen from the side of the waste-gate channel, as illustrated in FIG. 9. The second protrusion 28B has a height not greater than half the diameter D_1 of the waste-gate channel. This is because, if the height of the second protrusion 28B is greater than half the diameter D_1 of the waste-gate channel, an excessive load could be applied to the lever 15 when the waste-gate valve 24 opens. As illustrated in FIG. 8, the second protrusion 28B remains in a flow of exhaust gas having flowed the waste-gate channel 12 when the waste-gate valve 24 opens the waste-gate channel 12, which improves flow-rate controllability at the time of slight open of the waste-gate valve 24.

The waste-gate valve device 21 according to the second embodiment of the present invention is capable of applying more pressure to the drive-shaft side of the waste-gate valve 24 when the waste-gate valve 24 opens, and of reducing a flow-rate change amount at the time of slight open of the waste-gate valve 24. Accordingly, it is possible to improve flow-rate controllability of exhaust gas.

Third Embodiment

FIG. 10 is a schematic diagram of a waste-gate valve device according to the third embodiment of the present invention. FIG. 11 is a schematic diagram of the waste-gate valve illustrated in FIG. 10. A waste-gate valve device 31 according to the third embodiment of the present invention is not different from the waste-gate valve device 11 according to the above described first embodiment of the present invention, except for a protrusion 38 of a waste-gate valve 34. Thus, the same feature as that in the waste-gate valve device 11 according to the first embodiment of the present invention is indicated by the same reference numeral and not described in detail.

As illustrated in FIGS. 10 and 11, the waste-gate valve device 31 according to the present embodiment of the present invention includes the protrusion 38 integrally including a pressure-receiving portion and a reducing portion disposed on the waste-gate valve 34.

The pressure-receiving portion is to receive more pressure at the drive shaft of the waste-gate valve 34 when the waste-gate valve 34 opens. A side of the protrusion 38, according to the third embodiment of the present invention, closer to the drive shaft 16 forms a pressure-receiving portion. The pressure-receiving portion has a halved-cylindrical shape, as seen from the side of the waste-gate channel, as illustrated in FIG. 11.

The reducing portion is to reduce a flow-rate change amount at the time of slight open of the waste-gate valve 34. A side of the protrusion 38, according to the fourth embodiment, remote from the drive shaft 16 forms a reducing portion. The reducing portion has a halved truncated conical shape, as seen from the side of the waste-gate channel, as illustrated in FIG. 11.

The protrusion 38 has a height not greater than half the diameter D_1 of the waste-gate channel. This is because, if the height of the protrusion 38 is greater than half the diameter D_1 of the waste-gate channel, an excessive load could be applied to the lever 15 when the waste-gate valve 34 opens. As illustrated in FIG. 10, the protrusion 38 remains in a flow

10

of exhaust gas having flowed through the waste-gate channel 12 when the waste-gate valve 34 opens the outlet of the waste-gate channel 12, which improves flow-rate controllability at the time of slight open.

The waste-gate valve device 31 according to the third embodiment of the present invention is capable of applying more pressure to the drive-shaft side of the waste-gate valve 34 when the waste-gate valve 34 opens, and of improving flow-rate controllability at the time of slight open of the waste-gate valve 34.

Fourth Embodiment

FIG. 12 is a schematic diagram of a waste-gate valve device according to the fourth embodiment of the present invention. FIG. 13 is a schematic diagram of the waste-gate valve illustrated in FIG. 12. A waste-gate valve device 41 according to the fourth embodiment of the present invention is not different from the waste-gate valve device 11 according to the above described first embodiment of the present invention, except for protrusions 48A, 48B of a waste-gate valve 44. Thus, the same feature as that in the waste-gate valve device 11 according to the first embodiment of the present invention is indicated by the same reference numerals and not described in detail.

As illustrated in FIGS. 12 and 13, the waste-gate valve device 41 according to the fourth embodiment of the present invention includes a pressure-receiving portion (the first protrusion 48A) and a reducing portion (the second protrusion 48B) disposed on the waste-gate valve 44.

The pressure-receiving portion is to receive more pressure at a drive-shaft side of the waste-gate valve 44 when the waste-gate valve 44 opens. As illustrated in FIG. 12, the pressure-receiving portion according to the third embodiment of the present invention includes the first protrusion 48A disposed in a region closer to a surface facing the waste-gate channel 12, in the waste-gate valve 44. The first protrusion 48A is disposed so as to form a recess portion between the first protrusion 48A and the reducing portion (the second protrusion 48B), and has an arc shape as seen from the side of the waste-gate channel, as illustrated in FIG. 13. The pressure-receiving portion (the first protrusion 48A) resists exhaust gas having flowed through the waste-gate channel 12, whereby a pressure is applied to the drive-shaft side of the waste-gate 24.

The reducing portion is to reduce a flow-rate change amount at the time of slight open of the waste-gate valve 44. As illustrated in FIG. 12, the reducing portion according to the fourth embodiment includes the second protrusion 48B disposed on a side remote from the drive shaft 16 of a surface facing the waste-gate channel 12, in the waste-gate valve 44. The second protrusion 48B is formed symmetric to the first protrusion 48A with respect to a horizontal line passing through the center of the waste-gate valve 44. Thus, the second protrusion 48B has an arc shape, as seen from the side of the waste-gate channel, as illustrated in FIG. 13. The second protrusion 48B has a height not greater than half the diameter D_1 of the waste-gate channel. This is because, if the height of the second protrusion 48B is greater than half the diameter D_1 of the waste-gate channel, an excessive load could be applied to the lever 15 when the waste-gate valve 44 opens. As illustrated in FIG. 13, the second protrusion 48B remains in a flow of exhaust gas having flowed through the waste-gate channel 12 when the waste-gate valve 44 opens the waste-gate channel 12, which improves flow-rate controllability at the time of slight open.

11

The waste-gate valve device **41** according to the fourth embodiment of the present invention is capable of applying more pressure to the drive-shaft side of the waste-gate valve **44** when the waste-gate valve **44** opens, and of improving flow-rate controllability at the time of slight open of the waste-gate valve **44**. Further, since the second protrusion **48B** is formed symmetric to the first protrusion **48A** with respect to a horizontal line passing through the center of the waste-gate valve **44**, it is possible to mount the waste-gate valve **44** to the lever **15** regardless of the vertical direction of the waste-gate valve **44**.

Fifth Embodiment

FIG. **14** is a schematic diagram of a waste-gate valve device according to the fifth embodiment of the present invention. A waste-gate valve device **51** according to the fifth embodiment of the present invention is not different from the waste-gate valve device **11** according to the above described first embodiment of the present invention, except for a valve body **57** of a waste-gate valve **54**. Thus, the same feature as that in the waste-gate valve device **11** according to the first embodiment of the present invention is indicated by the same reference numeral and not described in detail.

As illustrated in FIG. **14**, the waste-gate valve device **51** according to the fifth embodiment of the present invention is to reduce a load applied to the waste-gate valve **54**, and has a rim portion **57a** formed to have a shape of a curved surface, the rim portion **57a** being disposed on a seating side of the valve body **57**. Accordingly, exhaust gas having flowed through the waste-gate channel **12** flows along the rim portion **57a** at the seating side of the valve body **57**, which reduces a load applied to the waste-gate valve **54**.

The waste-gate valve device **51** according to the fifth embodiment of the present invention is capable of reducing a load applied to the waste-gate valve **54**. Accordingly, the waste-gate valve device **51** according to the fifth embodiment of the present invention is capable of improving flow-rate controllability at the time of slight open of the waste-gate valve **54**.

Sixth Embodiment

FIG. **15** is a schematic diagram of a waste-gate valve device according to the sixth embodiment of the present invention. FIG. **16** is a schematic diagram of the waste-gate valve illustrated in FIG. **15**. A waste-gate valve device **61** according to the sixth embodiment of the present invention is not different from the waste-gate valve device **11** according to the above described first embodiment of the present invention, except for a protrusion **68** of a waste-gate valve **64**. Thus, the same feature as that in the waste-gate valve device **11** according to the first embodiment of the present invention is indicated by the same reference numeral and not described in detail.

As illustrated in FIGS. **15** and **16**, the waste-gate valve device **61** according to the sixth embodiment of the present invention includes a protrusion **68** disposed on a surface facing the waste-gate valve channel **12**, similarly to the waste-gate valve **11** according to the first embodiment of the present invention. The protrusion **68** according to the sixth embodiment of the present invention further includes a recess portion **68a** formed on the protrusion **68** of the present embodiment of the present invention.

The waste-gate valve **64** of the waste-gate valve device **61** according to the sixth embodiment of the present invention can have less weight than the waste-gate valve **14** of the

12

waste-gate valve device **11** according to the above described first embodiment. Further, a drift is caused by the recess portion **68a**, which makes it possible to improve flow-rate controllability at the time of slight open of the waste-gate valve **64**.

Seventh Embodiment

FIG. **17** is a schematic diagram of a waste-gate valve device according to the seventh embodiment of the present invention. A waste-gate valve device **71** according to the seventh embodiment of the present invention is not different from the waste-gate valve device **11** according to the above described first embodiment of the present invention, except for a protrusion **78** of a waste-gate valve **74**. Thus, the same feature as that of the waste-gate valve according to the first embodiment of the present invention is indicated by the same reference numeral and not described in detail.

As illustrated in FIG. **17**, the waste-gate valve device **71** according to the seventh embodiment of the present invention includes the protrusion **78** disposed on a surface facing the waste-gate valve channel **12**, similarly to the waste-gate valve **11** according to the first embodiment of the present invention. The protrusion **78** according to the seventh embodiment of the present invention includes an expanded portion **78a** such that a base portion of the protrusion **18** according to the above described first embodiment of the present invention expands along an inner periphery of the expanded portion **78**.

The waste-gate valve device **71** according to the seventh embodiment of the present invention is capable of avoiding stress concentration on a boundary between the valve body **17** and the protrusion **78**.

Eighth Embodiment

FIG. **18** is a schematic diagram of a waste-gate valve device according to the eighth embodiment of the present invention. As illustrated in FIG. **18**, a waste-gate valve device **81** according to the eighth embodiment of the present invention is different from the waste-gate valve **11** according to the above described first embodiment of the present invention in that a waste-gate valve **84** (valve body **87**) is rigidly fixed to a lever **85**.

With the waste-gate valve device **81** according to the eighth embodiment of the present invention, it is possible to prevent chattering (extremely high-speed mechanical vibration) of the waste-gate valve **84** while there is a little leakage of exhaust gas.

Ninth Embodiment

FIG. **19** is a schematic diagram of a waste-gate valve device according to the ninth embodiment of the present invention. As illustrated in FIG. **19**, the waste-gate valve device **91** according to the ninth embodiment of the present invention is aimed at improvement of a sealing property (sealability) of the waste-gate valve **94**, and the valve body **97** includes an elastic deformation part disposed between an end portion **97A** for opening and closing the waste-gate channel **12** and a base portion **97B** mounted to a lever **95**. The elastic deformation part according to the ninth embodiment includes a slit **97C**. In this way, the rigidity of the end portion **97A** of the valve body **97** is reduced, and the end portion **97A** of the valve body **17** warps when the waste-gate valve **94** closes the waste-gate channel **12** (elastic deformation).

13

With the waste-gate valve **91** according to the ninth embodiment of the present invention, the end portion **97A** of the valve body **17** warps when the waste-gate valve **94** closes the waste-gate channel **12**, and sealability of the waste-gate valve **94** is ensured.

Tenth Embodiment

FIG. **20** is a schematic diagram of a waste-gate valve device according to the tenth embodiment of the present invention. FIG. **21** is a schematic diagram illustrating a drive shaft and a bush supporting the drive shaft. As illustrated in FIG. **20**, a waste-gate valve device **101** includes a turbine housing (not illustrated) with a waste-gate channel through which exhaust gas bypasses a turbine, and a waste-gate valve **104** for opening and closing the waste-gate channel. The waste-gate valve **104** is fixed to an end of a drive shaft **106** via a lever **105** and pivots about an axis passing through the center of the drive shaft **106**, whereby the waste-gate channel is opened and closed. A lever pin **161** is disposed on the other end of the drive shaft **106**, and a rod **191** disposed on an actuator **109** is coupled to the lever pin **161**. Accordingly, when the actuator **109** is driven, the drive shaft **106** revolves via the rod **191** and the lever pin **161**, and the waste-gate valve **104** opens and closes the waste-gate channel.

Meanwhile, the waste-gate valve device **101** according to the tenth embodiment of the present invention may include a tapered surface **163** to prevent uneven contact of the drive shaft **106** with a bush **162** supporting the drive shaft **106**. Specifically, as illustrated in FIG. **21**, the tapered surface **163** is formed to have an inner periphery narrowed at the center in the vertical direction and widened at an upper part and a lower part in the vertical direction so that the drive shaft **106** contacts the tapered surface **163** if tilted. Further, the drive shaft **106** is thinned at a stepped portion **164** at the center in the vertical direction, which prevents the drive shaft **106** from being chipped by the narrowed inner periphery.

The waste-gate valve device **101** according to the tenth embodiment of the present invention may be capable of preventing uneven contact of the drive shaft **106** with the bush **162** supporting the drive shaft **106** and thus preventing generation of an edge surface pressure.

Eleventh Embodiment

FIG. **22** is a schematic diagram of a waste-gate valve device according to the eleventh embodiment of the present invention. As illustrated in FIG. **22**, a waste-gate valve device **111** includes a turbine housing (not illustrated) with a waste-gate valve channel through which exhaust gas bypasses a turbine, and a waste-gate valve **114** for opening and closing the waste-gate channel. The waste-gate valve **114** is fixed to an end of a drive shaft **116** via a lever **115** and the drive shaft **116** is supported by a bush **1162** disposed on the turbine housing. In this way, the waste-gate valve **114** pivots about an axis passing through the center of the drive shaft **116**, and opens and closes the waste-gate channel **12**. A lever pin **1161** is disposed on the other end of the drive shaft **116**, and a rod **1191** disposed on an actuator **119** is coupled to the lever pin **1161**. The lever pin **1161** and the actuator **119** are disposed so that a pressure direction of exhaust gas applied to the waste-gate valve **114** coincides with an operational direction of the actuator **119**. Specifically, as illustrated in FIG. **22**, the lever pin **1161** and the

14

actuator **119** are disposed so that the waste-gate valve **114** closes the waste-gate channel after the actuator **119** pushes out the rod **1191**.

As described above, with the lever pin **1161** and the actuator **1191** being disposed so that the waste-gate valve **114** closes the waste-gate channel when the actuator **119** pushes out the rod **1191**, a pressure direction of exhaust gas applied to the waste-gate valve **114** coincides with an operational direction of the actuator **119**. In this way, it is possible to prevent inclination of the drive shaft **1161** in a bush. As a result, it is possible to reduce leakage of exhaust gas outside the turbine housing through clearance between the drive shaft **116** and the bush **1162**.

As described above, the waste-gate valve **114** according to an embodiment of the present invention is capable of preventing the drive shaft **116** from inclining in a bush because a pressure direction of exhaust gas applied to the waste-gate valve **114** coincides with an operational direction of the actuator **119**. As a result, leakage of exhaust gas outside the turbine housing through clearance between the drive shaft **116** and the bush **1162** is prevented. Further, as a result, the drive shaft **116** and the bush **1162** contact each other via a larger contact area, which makes it possible to achieve an effect to reduce abrasion of the drive shaft **116**.

INDUSTRIAL APPLICABILITY

As described above, the waste-gate valve device according to the present invention is capable of improving flow-rate controllability at the time of slight open, and can be suitably applied to a waste-gate valve device which diverts a part of exhaust gas, in a supercharged engine equipped with a turbocharger, to adjust a flow rate of exhaust gas entering the turbine.

DESCRIPTION OF REFERENCE NUMERALS

- 1 Waste-gate valve device
- 2 Waste-gate channel
- 2A Widened portion
- 3 Turbine housing
- 4 Waste-gate valve
- 5 Lever
- 6 Drive shaft
- 7 Valve body
- 8 Protrusion
- D₁ Diameter of waste-gate channel
- D₂ Flow path diameter of merging portion
- D₃ Outlet diameter of waste-gate channel
- P_f Expansion surface pressure
- 11 Waste-gate valve device
- 12 Waste-gate channel
- 12A Widened portion
- 13 Turbine housing
- 14 Waste-gate valve
- 15 Lever
- 16 Drive shaft
- 17 Valve body
- 18 Protrusion
- 21 Waste-gate valve device
- 24 Waste-gate valve
- 28A First protrusion
- 28B Second protrusion
- 31 Waste-gate valve device
- 34 Waste-gate valve
- 38 Protrusion
- 41 Waste-gate valve device

15

44 Waste-gate valve
 48A First protrusion (pressure-receiving portion)
 48B Second protrusion (reducing portion)
 51 Waste-gate valve device
 54 Waste-gate valve
 57 Valve body
 57a Rim portion
 61 Waste-gate valve device
 64 Waste-gate valve
 68 Protrusion
 68a Recess portion
 71 Waste-gate valve device
 74 Waste-gate valve
 78 Protrusion
 78a Expanded portion
 81 Waste-gate valve device
 84 Waste-gate valve
 85 Lever
 87 Valve body
 91 Waste-gate valve device
 94 Waste-gate valve
 95 Lever
 97 Valve body
 97A End portion
 97B Base portion
 97C Slit
 101 Waste-gate valve device
 104 Waste-gate valve
 105 Lever
 106 Drive shaft
 161 Lever pin
 162 Bush
 163 Tapered surface
 164 Stepped portion
 109 Actuator
 191 Rod
 111 Waste-gate valve device
 114 Waste-gate valve
 115 Lever
 116 Drive shaft
 1161 Lever pin
 1162 Bush
 119 Actuator
 1191 Rod

The invention claimed is:

1. A waste-gate valve device, comprising:

a turbine housing comprising a waste-gate channel through which exhaust gas bypasses a turbine and a merging section where exhaust gas having flowed through the waste-gas channel merges with exhaust gas having passed through the turbine; and

a waste-gate valve configured to open and close an outlet of the waste-gate channel, the waste-gate valve comprising

a valve body configured to open and close the outlet of the waste-gate channel, and

a protruding member configured to be housed in the waste-gate channel when the valve body closes the outlet of the waste-gate channel,

wherein the waste-gate channel has a first flow-path diameter (D_1) at an input of the waste-gas channel and the merging section of the turbine housing has a second flow-path diameter (D_2),

wherein the waste-gate channel ensures a maximum flow rate of exhaust gas at a time when the waste-gate valve is fully open,

16

wherein a flow-path cross-sectional area ratio of the waste-gate channel to the merging section of the turbine housing is not more than 0.2,

wherein the waste-gate channel has a third flow-path diameter (D_3) which is greater than the first flow-path diameter at the outlet of the waste-gate channel, where the flow-path diameter of the waste-gate channel increases forming a curve in cross section and having a flow-path cross sectional area which increases from the input of the waste-gas channel to the merging section of the turbine housing, and

wherein the protruding member includes

a first protrusion that receives, when the waste-gate valve is opened, a pressure of exhaust gas flowing through the waste-gate channel by partially blocking the flow-path of the outlet of the waste-gate channel in a region close to a shaft supporting the waste-gate valve when the waste-gate valve is opened, and

a second protrusion that reduces, when the waste-gate valve is being opened, the flow of exhaust gas flowing through the waste-gate channel by partially blocking the flow-path of the outlet of the waste-gate channel in a region remote from the shaft when the waste-gate valve is opened.

2. The waste-gate valve device according to claim 1, wherein the first flow-path diameter (D_1) of the waste-gate channel satisfies a following expression 1, with respect to a relationship to the second flow-path diameter (D_2)

$$D_1 \leq 0.469 \times D_2 - 0.5 \quad (\text{Expression 1}).$$

3. The waste-gate valve device according to claim 1, wherein the third flow-path diameter (D_3) satisfies a following expression 2, with respect to a relationship to the first flow-path diameter (D_1)

$$D_3 \geq 1.049 D_1 \quad (\text{Expression 2}).$$

4. The waste-gate valve device according to claim 1, wherein the first protrusion is formed in the region close to the shaft, and the second protrusion is formed in the region remote from the shaft.

5. The waste-gate valve device according to claim 1, wherein the first protrusion is formed in an arc shape which forms a recess between the first protrusion and the second portion.

6. The waste-gate valve device according to claim 1, wherein the protruding member further includes a recess which receives exhaust gas flowing through the waste-gate channel.

7. The waste-gate valve device according to claim 1, wherein a base portion of the protruding member includes an expanded portion which expands along an inner periphery of the curve formed by the increase of the flow-path diameter of the waste-gate channel.

8. The waste-gate valve device according to claim 1, wherein the valve body has a rim portion disposed on a seating side of the valve body and formed into a shape of a curved surface.

9. The waste-gate valve device according to claim 1, wherein the valve body comprises

an end portion for opening and closing the waste-gate channel,

a base portion, and

an elastic-deformation portion disposed between the end portion and the base portion and configured to warp the end portion.

17

10. The waste-gate valve device according to claim 1, further comprising:

a drive shaft to which the waste-gate valve is fixed; and
a bush supporting the drive shaft,
wherein a tapered surface is formed on an inner peripheral
surface of the bush. 5

11. The waste-gate valve device according to claim 1, further comprising:

a drive shaft comprising an end to which the waste-gate
valve is fixed; 10
a bush supporting the drive shaft;
a lever pin disposed on another end of the drive shaft; and
an actuator comprising a rod coupled to the lever pin,
wherein the lever pin and the actuator are disposed so that
a pressure direction applied to the waste-gate valve 15
coincides with an operational direction of the actuator.

* * * * *

18